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Non-grid bedside chest imaging

Improving image quality and workflow using fractional multiscale image processing

White paper

AGFA

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Optimizing Image Quality and Workflow for Bedside Imaging

Agfa provides fractional multiscale image processing with dedicated parameter selection to improve image detail and contrast on non-grid bedside chest images.

Executive summary

Agfa's MUSICA image processing is designed to deliver consistently high image quality, even when scatter is present. MUSICA3 determines the frequency of scatter and uses multifrequency subtraction processing to reduce the appearance of scatter. This yields significant improvement in image contrast for bedside chest images taken without an anti-scatter grid.

Introduction

With the advent of mobile digital radiography systems, combined with an aging population, there has been a continual increase in the percentage of bedside (portable) chest radiographs carried out in hospitals. In some cases, up to 50% of in-hospital digital radiography procedures are now bedside chest exams.

Grid Limitations

Although using grids is optimal from a physics standpoint, in a bedside imaging setting there are a number of resulting challenges:

- Grids need to be properly centered and positioned
- Grids get damaged over time
- Grids may create aliasing artefacts in the images
- Grids typically require a higher radiation dose
- Grids require longer exposure times

Because of these time- and effort-consuming requirements, the use of anti-scatter grids is often avoided in bedside chest radiography.

Anti-scatter grids are normally recommended for use with chest radiography in order to improve image quality. Using grids can result in improved contrast detail by reducing the amount of scatter radiation reaching the detector. This is particularly true for medium to large-sized patients.

But delivering acceptable image quality from bedside imaging can often be challenging for a technologist, due to equipment and exposure limitations as well as patient pathology.

Agfa's MUSICA image processing is designed to optimize detail contrast under all conditions, whether or not a grid is used. Thus, there is no need for it to mimic the effect of a grid. In this regard, it is conceptually different from conventional image processing, and can process chest images taken with or without a grid, without distinction, using the same algorithm [1] [2].

This white paper demonstrates MUSICA's advanced Fractional Multiscale Processing (FMP) technology for these (difficult) bedside chest exposures, and shows how Agfa uses state-of-the-art technology to improve the delivery of quality daily care for critically ill patients, as stated by a participating radiologist.

Agfa's approach to bedside chest radiography

Agfa was the first manufacturer to develop image processing algorithms specifically for chest radiography, and for many years MUSICA has optimized non-grid bedside image contrast.

While other technologies attempt to produce an image that resembles the equivalent image taken with a physical anti-scatter grid, MUSICA intrinsically performs scatter subtraction based on an analysis of the image frequencies. Detail contrast can thus be improved, almost up to the level of a properly exposed grid image.

Introduced with MUSICA3, Fractional Multiscale Processing (FMP) further optimizes lung vessel detail, while minimizing the effects of noise and scatter radiation.

What can MUSICA3 and Fractional Multiscale Processing (FMP) do for non-grid bedside chest exposures?

What is Fractional Multiscale Processing (FMP)?

FMP is the new mathematical substructure of Agfa's image processing software, which further decomposes image components into elementary fractions for separate processing. FMP results in a more accurate multi-scale enhancement model, a balanced participation of all filter kernel pixels in the enhancement process, and better preservation of low-contrast details next to high-contrast steps.

In addition to the Fractional Multiscale Processing, MUSICA allows specific tuning or parameter adjustment for non-grid chest imaging, providing additional enhancement. These parameters are versatile and, unlike other products on the market, no system calibration or other pre-requisite is required. The MUSICA concept thus supports greater flexibility to adapt to customer-specific preferences.

The MUSICA3 Chest+ package includes an extra parameter set for optimal bedside chest image quality and facilitates a mix of grid and non-grid imaging workflows.

Remark: This application does not replace grid exams in all circumstances (nor does any other technology). Exams taken with a grid under optimal conditions (non-bedside images) can still be superior.

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Clinical Image Quality Study: Test set-up

To determine the extent to which image processing enhancement can improve the detail contrast on non-grid chest images, a study was carried out using phantom and clinical images.

Phantom tests

An internal bench test was performed using chest phantoms to simulate both normal-weight and obese patients. This study showed that MUSICA3 chest processing with parameter enhancement could potentially improve the image quality of non-grid chest images to nearly that of a standard MUSICA (Genrad) processed grid image (with a dose reduction factor of 1.6 for the non-grid images).

Clinical tests

However, this phantom testing did not reveal how pathology would be affected by the extra enhancement, and thus what degree of enhancement would be acceptable for radiologists in actual clinical use, depending on patient size and variable X-ray doses. Therefore, a study based on clinical images, including readings by radiologists, was initiated. An elaborated study design was used to derive the optimal MUSICA3 parameter settings, as well as contextual information.

For this purpose, clinical, non-grid bedside chest images from various ICU units were collected from a total of five different hospital sites in the USA, Germany and Belgium. A sample of 25 patient cases was used for evaluation, including DR and CR technology, as well as a representative dose range, different patient sizes and various pathologies. 'For processing' raw images from these patient cases were reprocessed with established processing (MUSICA2 Genrad) and with the newest version of Agfa's multiscale processing (MUSICA3 Chest, including FMP) at default settings, with three different levels of processing enhancement (weak-moderate-strong).

The assessment was carried out by six radiologists (two each from the USA, Germany and Belgium). All are experienced radiologists familiar with chest imaging; three are dedicated thorax radiology specialists.

In this clinical evaluation, the diagnostic equivalence or potential improvement of the enhanced 3 Chest image processing (in three levels) was assessed by comparing it to the non-enhanced MUSICA3 and MUSICA2 Genrad image processing. All presented images were taken without an anti-scatter grid and displayed on high-quality diagnostic monitors.

For each (non-grid) image comparison, the radiologist was asked to indicate a preferred reference image between REF1 (using MUSICA3 Chest processing) and REF2 (using MUSICA2 Genrad processing), both using the default image processing settings, and a score for the overall image quality of both reference images. For the test-image comparison, REF1 was displayed on the left monitor, and used as guidance for the (absolute) overall image quality score of the test images.

The three test images being evaluated, varying from weak to strong enhancement, were displayed on the right monitor. The radiologist was asked to scroll through the images and select the test image (or enhancement level) that was preferred, compared to the REF image on the other monitor. The score for the preferred test image, as well as scores for the other test images, was recorded.

The following MUSICA3 chest parameter settings were used for the three enhancements:

	Contrast	Sharpness	Brightness
Test image 1 (TC1) - weak enhancement	+6	0	0
Test image 2 (TC2) - moderate enhancement	+13	-2	0
Test image 3 (TC3) - strong enhancement	+20	-2	0

Chest image without anti-scatter grid using established version of multiscale processing (REF2); chest image using latest version of multiscale processing and default settings (REF1); test images using latest version of multiscale processing and different enhancement levels (weak-moderate-strong).

Image example

REF1: MUSICA3 Chest default

REF2: MUSICA2 Genrad default

Test image 1:
weak enhancement

Test image 2:
moderate enhancement

Test image 3:
strong enhancement

For the ratings, the scoring scale below (absolute scoring) was used:

Overall image quality level

NA		Adequate			Good			Excellent		
0	1	2	3	4	5	6	7	8	9	10

NA: Not Acceptable

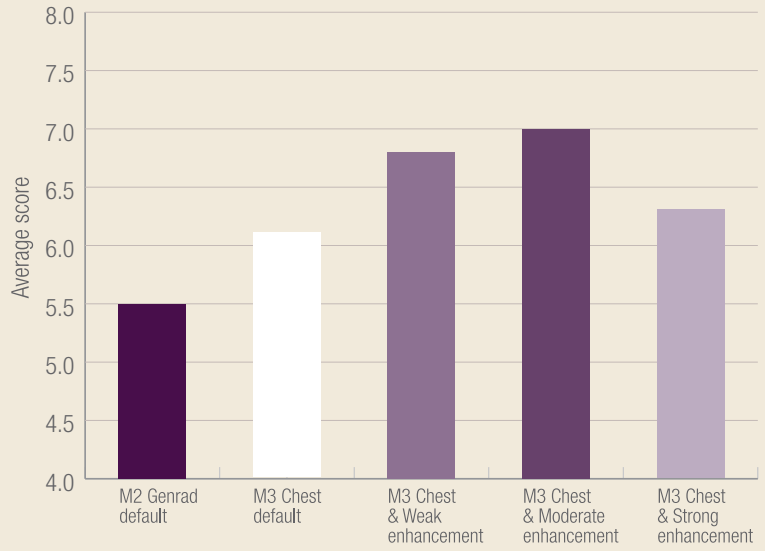
The reading results were statistically analyzed. A T-test with a confidence level of 95% was used to determine whether the mean of the reading result for overall image quality by all six radiologists was significantly different from the reference.

Clinical Image Quality Study: Results

Readings of the optimized image sets revealed a significant improvement for both the small and moderate enhancement levels across all readers and images, as well as a stronger improvement for images of normal-weight to obese patients.

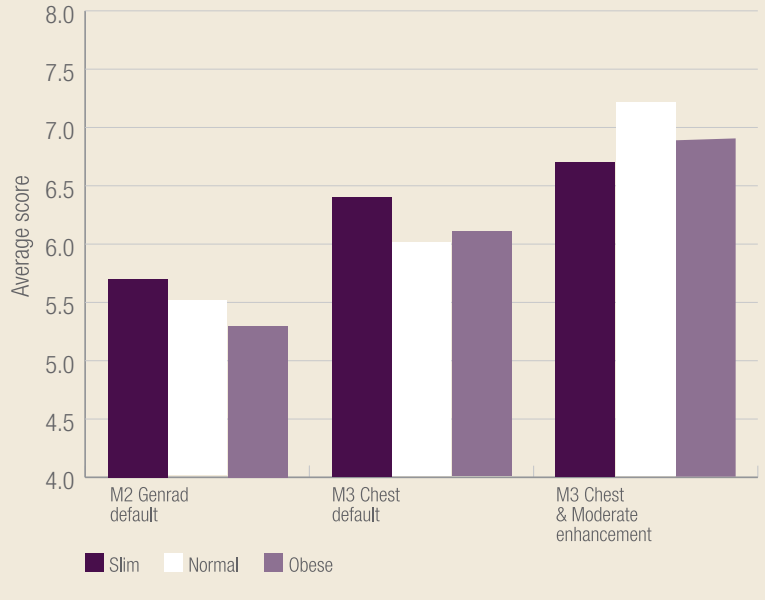
For the non-grid bedside chest images - a difficult group of chest images - MUSICA3 Chest default was preferred over MUSICA2 Genrad. The parameter adjustment of MUSICA3 Chest resulted in an additional, significant contrast improvement (in the order of 1.5 to 2 points on a scale of 10 when compared to MUSICA2 Genrad).

Graphic 1: Non-grid bedside - All 25 images



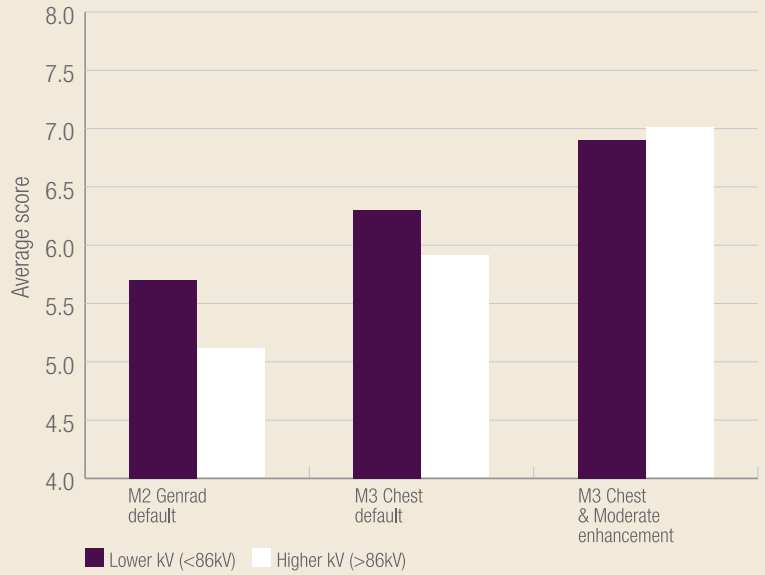
The improvement proved to be most effective in the target group of normal-weight to obese patients, exposed without grid. This is the most critical category, as there is more impact from scatter on the overall image quality.

Graphic 2: Patient size



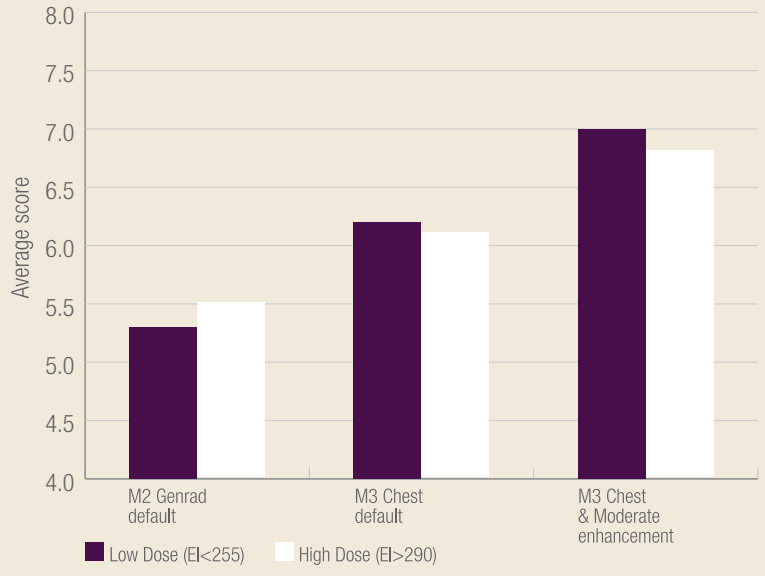
The readings demonstrated that the improvement from MUSICA3 with additional parameter enhancement was more pronounced at higher kV:

Graphic 3: Non-grid bedside - kV



The improvement from MUSICA3 with additional parameter enhancement also proved to be somewhat stronger at a lower dose:

Graphic 4: Non-grid bedside - dose



Practical implementation/flexibility

Unlike other non-grid image processing solutions, parameter optimizations are easy and straightforward to implement with this solution. On the Agfa MUSICA workstation an (additional) exam for 'bedside chest exposure without grid' can be created easily in the examination tree and selected as needed. This exam can be linked to the MUSICA3 Chest+ package. The preconfigured image processing parameters will then be automatically applied on the exam level, eliminating the need to re-adjust image processing or window width and level for each exam taken.

Clinical Image Quality Study: Conclusions

MUSICA3 state-of-the-art multiscale processing yields significant improvement in image contrast for bedside chest images of normal-weight to obese patients taken without anti-scatter grid. This is particularly noticeable with obese patients. Grid artifacts, long exposure times and undiagnostic images due to misaligned grids can be avoided.

For non-grid bedside chest images, a statistically significant improvement was seen when using fractional multiscale processing (MUSICA3) at the minimum and moderate enhancement settings over standard multiscale image processing (MUSICA2) across all readers and patient sizes (thin to obese).

An even greater improvement was seen when the thin patients were excluded. For normal-weight to obese patients, using minimum enhancement, 81% of the images were rated better than the standard multiscale processing.

With the moderate enhancement, 77% of the images were rated better. The improvement was more pronounced for images done at higher kVp as well as for images done with lower doses. Image enhancement can be easily optimized using the MUSICA image processing adjustment parameters.

Also regarding the MUSICA3 default processing for chest, the moderate enhancement was shown to offer a statistically significant improvement for non-grid bedside chest images.

Commercially, this MUSICA3 chest enhancement image processing is referred to as 'Chest+'.

Clinical Practice: MUSICA3 Chest+ versus anti-scatter grids

MUSICA3 Chest+ offers valuable benefits for bedside imaging, enhancing patient comfort, reducing the need for bulky grids and making it easier and faster to position the detector. Chest+ can be used with both DR and CR bedside chest exams. As a radiologist stated: "chest+ brings benefits for critically ill patients".

In a clinical study, 25 non-grid bedside chest images were evaluated, comparing MUSICA3 Chest+ to MUSICA2 Genrad image processing. These images were further compared to images from the same patient acquired on another day using a physical anti-scatter grid (ratio 6:1) and increased X-ray dose, and processed using MUSICA2 Genrad image processing.

While the technologists were trained on the proper use of an anti-scatter grid, this comparison points to many of the typical shortcomings of chest exams taken under these conditions, including grid handling and alignment, variation in patient position and dose (with grid and without grid), and the time difference (and possible pathology change) between the two exposures.

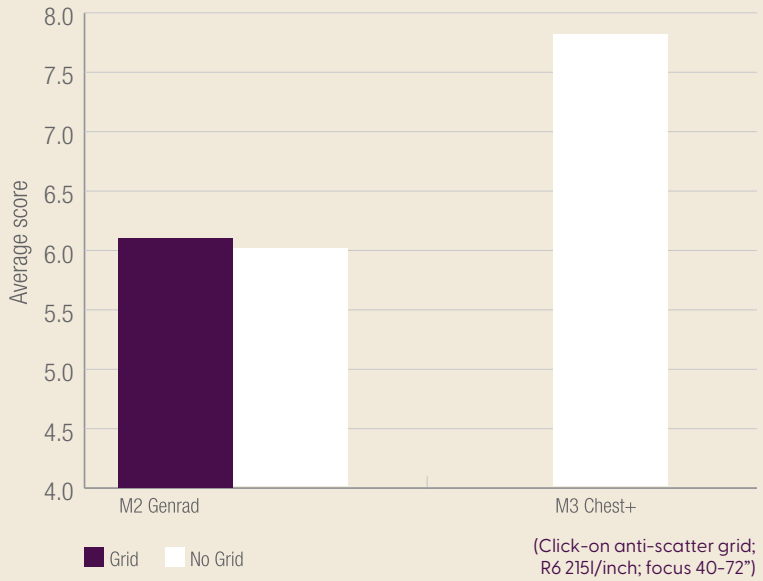
Readings of these image sets were carried out by two experienced radiologists from the hospitals from which the bedside chest images were acquired (specifically, from the ICUs of two typical, larger German hospitals). Both DR and CR images were included. Features for daily control in ICU were identified by the readers, and the images were rated on a quality scale from 1 to 10 (absolute scoring).

The overall image quality difference between MUSICA3 Chest+ and MUSICA2 Genrad processing was proven to be significant by means of a T-test with a confidence level of 95%.

Clinical Practice: Result

The reading results revealed a clear preference for MUSICA3 Chest+ processing. This preference for MUSICA3 Chest+ was confirmed by additional readers, specialized in chest radiology, from the USA.

Graphic 5: Averages DR images (96kV) – dose ratio with grid of 1.6



(Click-on anti-scatter grid; R6 215l/inch; focus 40-72")

Reference image acquired without grid

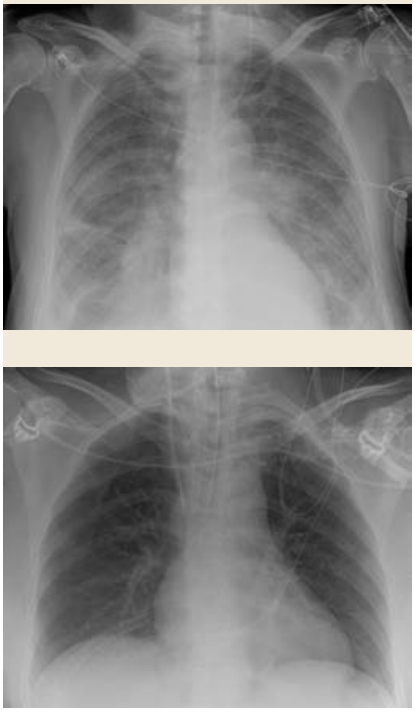


Image of the same patient acquired on a different day. A grid was used and X-ray dose was increased by a factor of 1.6

Same exposure but processed with MUSICA3 Chest+

Clinical Practice: Conclusion

For bedside chest images, the clinical experience confirmed that MUSICA3 Chest+ was clearly preferred over MUSICA2 Genrad image processing; the MUSICA3 Chest+ non-grid images were rated significantly higher than the MUSICA2 Genrad images carried out with or without a grid.

Specifically, the radiologists felt that the improvement in lung field detail achieved with the MUSICA3 Chest+ image processing without a grid was greater than that achieved using MUSICA2 Genrad processing, even if a grid was used and at an increased dose.

The fact that using a grid and approximately 1.6 times higher dose yields little or no improvement in image quality for the bedside examinations may be attributed to the practical circumstances (and the shortcomings) of grid handling in this situation. In practice, the results for images taken of a patient in an X-ray room with a wallstand, more controlled conditions and different (higher) doses could be expected to yield more favorable results for the grid images.

However, for mobile non-grid imaging, optimal lung field visualization as provided by MUSICA3 Chest+ was seen by the radiologists as the most important aspect of a bedside chest examination. This potentially outweighs the additional improvement of the mediastinum gained by using a physical anti-scatter grid with MUSICA2 Genrad processing at a higher (1.6x) exposure.

About the authors

Lizy Verstreepen is based at Agfa's headquarters in Mortsel. She is a senior application specialist in image quality. She has previously carried out various comparisons of image quality in several applications, between internal and competitive systems. She holds a B.S. in Chemistry.

Friedrich Wanninger is based in Munich. As Agfa's application lead, he is one of the company's experts on image quality and flat panel detectors. He holds a M.Sc. degree in Medical Physics.

Bruce Apgar is based in Greenville, South Carolina (USA). He is application lead for imaging services and represents the company at several leading technical committees, including the American Association of Physicist in Medicine's (AAPM) task groups, and at the Medical Imaging and Technology Alliance (MITA). He has a B.S. in Imaging Science from Rochester Institute of Technology.

Bernd Hoberg is based in Bonn. He is product manager for DR for Agfa in Germany, Austria and Switzerland. He represents the company at several technical committees.

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[1] Introduction to MUSICA Technology (published November 2016 LL-ID: 51923562)
[2] "Next generation MUSICA: more from each image" Interview with Piet Vuylsteke, PhD, Senior Researcher and Jan Leeuws, Business Unit Manager Digital Radiography (Agfa THERE Magazine #15, published November 2013, LL-ID: 43304871)

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